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11 Jul 97

From: Director, Office of Naval Research, Seattle Regional Office, 1107 NE 45th St., Suite 350, Seattle, WA 98105

To: Defense Technical Center, Attn: P. Mawby, 8725 John J. Kingman Rd., Suite 0944, Ft. Belvoir, VA 22060-6218

Subj: RETURNED GRANTEE/CONTRACTOR TECHNICAL REPORTS

1. This confirms our conversations of 27 Feb 97 and 11 Jul 97. Enclosed are a number of technical reports which were returned to our agency for lack of clear distribution availability statement. This confirms that all reports are unclassified and are "APPROVED FOR PUBLIC RELEASE" with no restrictions.

2. Please contact me if you require additional information. My e-mail is *silverr@onr.navy.mil* and my phone is (206) 625-3196.

ROBERT J. SILVERMAN

To: Regional Director
    Team Leader
    ACO

This technical report was sent to <u>me</u> by DTIC because it <u>does not</u> include the DD-1498 form with the proper disclosure/distribution statement.

Please obtain this form with proper instructions and <u>return it and the technical report directly to DTIC</u>.

Also implement procedures with the contractor to correct this problem.

Thank You,

Jim Carbonara,
Director, Field Operations

Applied Physics Laboratory
College of Ocean and Fishery Sciences, University of Washington

28 November 1995
Serial 5C3743

To: Manuel E. Fiadiero, Code 322OM
Office of Naval Research
Ballston Tower #1
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Arlington, VA 22217-5660

From: Bruce M. Howe and James A. Mercer
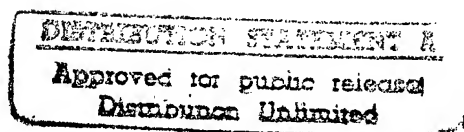
Subj: Annual Report

Encl: (1) Annual Report for Grant N00014-95-1-0266

1.   Enclosed is the first annual report for the project "Assimilating Tomography Data Into an Ocean Model."

James A. Mercer

cc: ONR Administrative Grants Officer
Director, Naval Research Laboratory
Defense Technical Information Center

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PI:	Bruce Howe and James Mercer
Title:	Assimilating Tomography Data into an Ocean Model
Category of research:	Ocean Modeling and Data Assimilation
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LONG TERM GOALS

The objective of this research is to examine how assimilated acoustic tomography data constrains an open ocean quasi-geostrophic circulation model and improves model output.

SCIENTIFIC AND TECHNOLOGICAL OBJECTIVES:

The primary scientific objective is to understand how line-integral measurements, such as tomographic measurements, improve the forecast skill of an ocean circulation model. In addition, we will quantify the improvement in the tomography array's spatial resolution and produce valuable qg-consistent ocean statistics for the Acoustic Mid-ocean Dynamics Experiment (AMODE) region.

BACKGROUND:

Observing and predicting the ocean's meso-scale circulation presents a formidable task for oceanographers. Ocean acoustic tomography uses travel times between acoustic sources and receivers to measure the ocean's low wavenumber sound speed (temperature) and current fields. These tomographic measurements of the ocean's interior sound speed field are intrinsically different from point current measurements or satellite sea surface measurements. We are performing experiments with simulated ocean data to determine the relative effectiveness of tomographic and point measurements in constraining a numerical circulation model.

APPROACH:

In order to understand the impact of tomographic data on the circulation model,

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we will use identical twin simulations with data assimilation using a non-linear quasi-geostrophic circulation model. The assimilation will use a sequential updating scheme based on Optimal Interpolation (OI). The OI assimilation of the data produces an optimized combination of model output and observations. Relative weights of observation and model output are based on a priori estimates of the model and observation error covariance. The identical twin simulations will be used to make comparisons between the assimilation results and the control ocean using a variety of error statistics to quantify the results. These error statistics will include comparisons of kinetic energy, potential energy, vorticity, and flux estimates.

ACCOMPLISHMENTS AND RESULTS:

The work using twin experiments is currently being done by Chris Walter, a graduate student in Geophysics at the University of Washington, in collaboration with Robert Miller at Oregon State University. We are presently evaluating the performance of tomographic and point temperature measurements using the Harvard Open Ocean Circulation Model. Figure 1 shows the configuration of the AMODE/MST tomographic array which is made up of 6 acoustic transceivers. Between each transceiver, 3 rays are used to model acoustic sum and difference travel times. Figure 1 also outlines the 1200x1200km domain of the control ocean which is used to generate the simulated data and the smaller 825x825km domain used in the assimilation .

Initial simulation experiments run in FY95 used a control ocean simulation generated by M. Rienecker for the MODE region approximately 500km north of the AMODE region. Strictly, these experiments where "fraternal-twin," i.e. the assimilation physics and the control ocean physics were not identical. They differed in the form of bottom topography, surface forcing, and buoyancy stratification. These experiments indicated that the error growth in the model could be constrained, but that the RMS error level was no better, or in some instances worse than that of simple objective analysis.

A new control ocean was simulated using parameters for the AMODE region. We attempted to alter the vertical structure of the model and make it better match the continuous set of modes which are necessary for acoustic simulations, but found that this gave unrealistic circulation model results (the variance of the interior field was not realistic.)

Continued work is needed to improve this control ocean's circulation and vertical structure. Figure 2 shows a set of preliminary assimilation results for the set of twin experiments which uses these continuous modes but has unrealistic circulation

dynamics. In FY96, we will optimize the assimilation, an iteration over an ensemble of forecast experiments will be performed to better estimate the forecast error statistics in FY96.

RELATIONSHIP TO OTHER PROJECTS: This work is a direct growth of two ONR funded activities: the AMODE-MST experiment, and the Committee on tomographic Data in Ocean Models. The data assimilation methods developed here are expected to be directly applicable for a wide range of circulation models and acoustic environments. Close coordination is maintained with related ONR projects at Oregon State University and Scripps Institute of Oceanography.
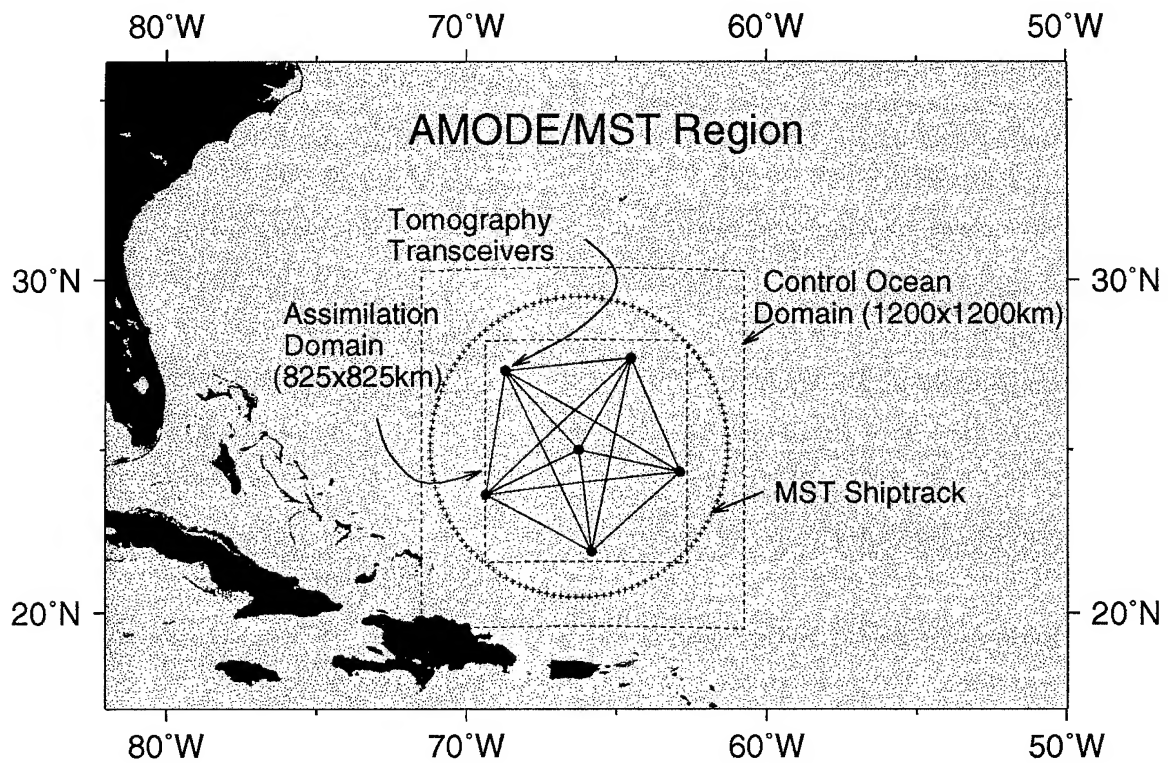
Figure 1: Acoustic Mid-Ocean Dynamics Experiment (AMODE) transceiver moorings are shown with black dots along with the Moving Ship Tomography (MST) circle. Dashed lines show the domain of the control run (larger square) and the assimilation run (smaller square).
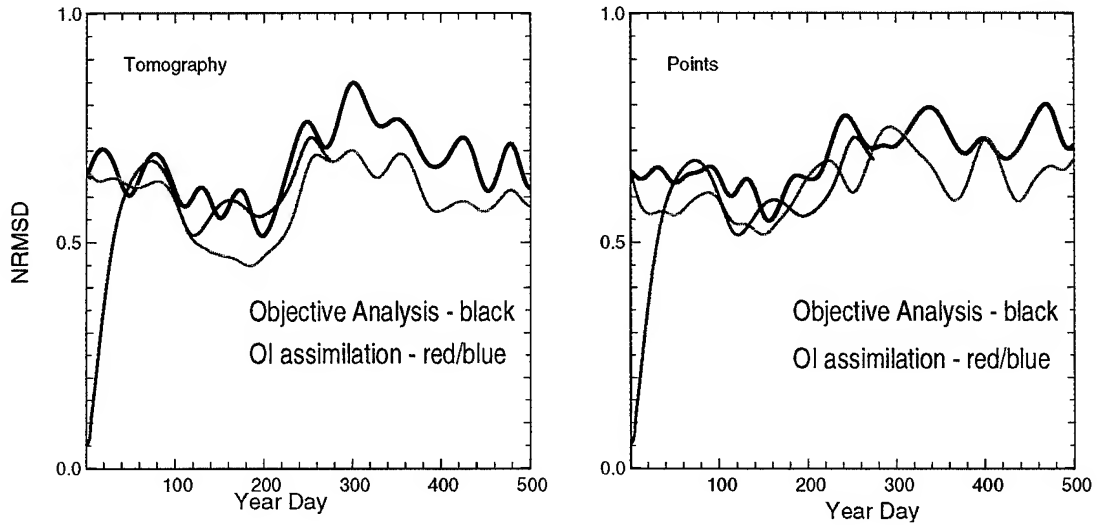
Normalized RMS Errors

Figure 2: Normalized RMS errors between the assimilation field's and the control ocean's first baroclinic mode as a function of integration time (tomography data on the left and point data on the right.) The tomographic data consisted of 15 source-receiver paths with 3 rays per path. The point data consisted of 4x4 array of point temperature measurements at three depths. Two assimilation curves (red and blue) are shown, one in which the initial field is identical to the objective analysis field and the other in which the initial field is specified exactly (0 RMS error.) The assimilation curves can be compared to the objective analysis curve which is shown in black.